

C L A I M S

1. A multi-axial angular velocity sensor for detecting angular velocity components about respective coordinate axes in a three-dimensional coordinate system, comprising:

5 an oscillator (130; 211; 241; 260; 321; 440; 550; 610) having mass;

10 a sensor casing (140; 220, 230; 270, 280, 290; 322, 330, 340; 450; 560; 620, 630, 660) for accommodating said oscillator therewithin;

15 connection means (110; 212; 252; 312; 410; 510; 640, 650) for connecting the oscillator to the sensor casing in a state having a degree of freedom such that the oscillator can move in respective coordinate axial directions;

20 excitation means (E0 to E5, F0 to F5; G0 to G10; D1 to D16; J1 to J6) for oscillating the oscillator in the respective coordinate axial directions; and

25 displacement detecting means (E0 to E5, F0 to F5; G0 to G10; Rx1 to Rx4, Ry1 to Ry4, Rz1 to Rz4; D1 to D16; J1 to J6) for detecting displacements in the respective coordinate axial directions of the oscillator.

2. A multi-axial angular velocity sensor as set forth in claim 1,

25 wherein there is further provided control means (740) for executing:

first detecting operation for giving an indication to the excitation means so as to oscillate the oscillator in a first coordinate axial direction, and for giving an indication to the displacement detecting means so as to 5 detect a displacement in a second coordinate axial direction of the oscillator, thus to determine an angular velocity component about a third coordinate axis on the basis of the detected displacement;

a second detecting operation for giving an indication to the excitation means so as to oscillate the oscillator in the second coordinate axial direction, and for giving an indication to the displacement detecting means so as to detect a displacement in the third coordinate axial direction of the oscillator, thus to determine an angular velocity component about the first coordinate axis on the basis of 15 the detected displacement; and

a third detecting operation for giving an indication to the excitation means so as to oscillate the oscillator in the third coordinate axial direction, and for giving an indication to the displacement detecting means so as to 20 detect a displacement in the first coordinate axial direction of the oscillator, thus to determine an angular velocity component about the second coordinate axis on the basis of the detected displacement.

3. A multi-axial angular velocity sensor as set forth in claim 2,

wherein the control means is caused to further execute a fourth detecting operation for giving an indication to the excitation means so as not to oscillate the oscillator in any direction, and for giving an indication to the displacement detecting means so as to detect displacements in all the first to third coordinate axial directions of the oscillator, thus to determine acceleration components exerted in respective coordinate axial directions on the basis of the detected displacements.

4. A multi-axial angular velocity sensor for detecting angular velocity components about respective coordinate axes in a three-dimensional coordinate system, comprising:

a flexible substrate (110; 210; 250; 313) having flexibility;

a fixed substrate (120; 230; 290; 340) disposed so as to oppose the flexible substrate with a predetermined distance therebetween above the flexible substrate;

an oscillator (130; 211, 241; 260; 321) fixed on the lower surface of the flexible substrate;

a sensor casing (140; 220, 230; 270, 280, 290; 322, 330, 340) for supporting the flexible substrate and the fixed substrate and accommodating the oscillator therewithin;

excitation means (E0 to E5, F0 to F5; G0 to G10) for oscillating the oscillator in respective coordinate axial directions; and

displacement detecting means (E0 to E5, F0 to F5; 5 G0 to G10) for detecting displacements in respective coordinate axial directions of the oscillator.

5. A multi-axial angular velocity sensor for detecting angular velocity components about respective coordinate axes in a three-dimensional coordinate system, comprising:

a flexible substrate (110; 250) having flexibility; a fixed substrate (120; 290) disposed so as to oppose the flexible substrate with a predetermined distance therebetween above the flexible substrate;

15 an oscillator (130; 260) fixed on the lower surface of the flexible substrate;

a sensor casing (140; 270, 280, 290) for supporting the flexible substrate and the fixed substrate and accommodating the oscillator therewithin;

20 a plurality of lower electrodes (F1 to F5) provided on an upper surface of the flexible substrate;

a plurality of upper electrodes (E1 to E5; E0) provided on a lower surface of the fixed substrate and disposed at positions respectively opposite to the plurality 25 of lower electrodes;

means (711, 712) for applying an a.c. signal

across a pair of lower and upper electrodes opposite to each other to thereby oscillate the oscillator in respective coordinate axial directions; and

means (721, 722) for detecting an electrostatic capacitance between a pair of lower and upper electrodes opposite to each other to thereby detect displacements in respective coordinate axial directions of the oscillator.

6. A multi-axial angular velocity sensor as set forth in claim 5,

wherein an XYZ three-dimensional coordinate system such that an X-axis and a Y-axis intersect with each other on a plane in parallel to a principal surface of the flexible substrate is defined; and

wherein a first lower electrode (F1) and a first upper electrode (E1) are disposed in a positive region of the X-axis, a second lower electrode (F2) and a second upper electrode (E2) are disposed in a negative region of the X-axis, a third lower electrode (F3) and a third upper electrode (E3) are disposed in a positive region of the Y-axis, a fourth lower electrode (F4) and a fourth upper electrode (E4) are disposed in a negative region of the Y-axis, and a fifth lower electrode (F5) and a fifth upper electrode (E) are disposed at a position corresponding to an origin.

7. A multi-axial angular velocity sensor as set forth in claim 6,

wherein there is further provided control means (740) for executing:

5 a first detecting operation for applying an a.c. signal across the fifth lower electrode (F5) and the fifth upper electrode (E5) and detecting, with the oscillator being oscillated in the Z-axis direction, a difference between an electrostatic capacitance between the third lower electrode (F3) and the third upper electrode (E3) and an electrostatic capacitance between the fourth lower electrode (F4) and the fourth upper electrode (E4), thus to detect an angular velocity component (ω_x) about the X-axis on the basis of said difference;

15 a second detecting operation for applying two a.c. signals having phases opposite to each other across the first lower electrode (F1) and the first upper electrode (E1) and across the second lower electrode (F2) and the second upper electrode (E2), respectively, and detecting, with the oscillator being oscillated in the X-axis direction, an electrostatic capacitance between the fifth lower electrode (F5) and the fifth upper electrode (E5), thus to detect an angular velocity component (ω_y) about the Y-axis on the basis of said electrostatic capacitance; and

25 a third detecting operation for applying two a.c. signals having phases opposite to each other across the

third lower electrode (F3) and the third upper electrode (E3) and across the fourth lower electrode (F4) and the fourth upper electrode (E4), respectively, and detecting, with the oscillator being oscillated in the Y-axis direction, 5 a difference between an electrostatic capacitance between the first lower electrode (F1) and the first upper electrode (E1) and an electrostatic capacitance between the second lower electrode (F2) and the second upper electrode (E2), thus to detect an angular velocity component (ω_z) about the Z- axis on the basis of said difference.

8. A multi-axial angular velocity sensor as set forth in claim 6,

wherein one party of the plural lower electrodes and the plural upper electrodes is constituted by a single 15 electrode layer (E0).

9. A multi-axial angular velocity sensor as set forth in claim 8,

wherein one of the flexible substrate and the 20 fixed substrate is constituted by conductive material, and the conductive substrate thus constituted itself is used as a single electrode layer.

25 10. A multi-axial angular velocity sensor as set forth in claim 5,

wherein an XYZ three-dimensional coordinate system such that an X-axis and a Y-axis intersect with each other on a plane in parallel to a principal surface of the flexible substrate is defined; and

5 wherein a first lower electrode (G1) and a first upper electrode (G6) are disposed in a first quadrant region with respect to the XY plane, a second lower electrode (G2) and a second upper electrode (G7) are disposed in a second quadrant region with respect to the XY plane, a third lower electrode (G3) and a third upper electrode (G8) are disposed in a third quadrant region with respect to the XY plane, a fourth lower electrode (G4) and a fourth upper electrode (G9) are disposed in a fourth quadrant region with respect to the XY plane, and a fifth lower electrode (G5) and a fifth upper electrode (G10) are disposed at a position corresponding to an origin.

11. A multi-axial angular velocity sensor as set forth in claim 10,

20 wherein there is further provided control means (740) for executing:

 a first detecting operation for applying an a.c. signal across the fifth lower electrode (G5) and the fifth upper electrode (G10), and detecting a displacement in the Y-axis direction with the oscillator being oscillated in the Z-axis direction, thus to detect an angular velocity

component (ω_x) about the X-axis on the basis of said displacement;

5 a second detecting operation for applying a first a.c. signal across the first lower electrode (G1) and the first upper electrode (G6) and across the fourth lower electrode (G4) and the fourth upper electrode (G9), applying a second a.c. signal having a phase opposite to that of the first a.c. signal across the second lower electrode (G2) and the second upper electrode (G7) and across the third lower electrode (G3) and the third upper electrode (G8), and detecting a displacement in the Z-axis direction of the oscillator with the oscillator being oscillated in the X-axis direction, thus to detect an angular velocity component (math> ω_y) about the Y-axis on the basis of said displacement;

15 and

20 a third detecting operation for applying a first a.c. signal across the first lower electrode (G1) and the first upper electrode (G6) and across the second lower electrode (G2) and the second upper electrode (G7), applying a second a.c. signal having a phase opposite to that of the first a.c. signal across the third lower electrode (G3) and the third upper electrode (G8) and across the fourth lower electrode (G4) and the fourth upper electrode (G9), and detecting a displacement in the X-axis direction of the oscillator with the oscillator being oscillated in the Y-axis direction, thus to detect an angular velocity component

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(ω_z) about the Z-axis on the basis of said displacement.

12. A multi-axial angular velocity sensor as set forth in claim 10,

5 wherein one party of the plural lower electrodes and the plural upper electrodes is constituted by a single electrode layer (G0).

10 13. A multi-axial angular velocity sensor as set forth in claim 12,

wherein one of the flexible substrate and the fixed substrate is constituted by conductive material, and the conductive substrate thus constituted itself is used as a single electrode layer.

15 14. A multi-axial angular velocity sensor for detecting angular velocity components about respective coordinate axes in a three-dimensional coordinate system, comprising:

20 a flexible substrate (313) having flexibility;

a fixed substrate (340) disposed so as to oppose the flexible substrate with a predetermined distance therebetween above the flexible substrate;

25 an oscillator (321) fixed on the lower surface of the flexible substrate;

a sensor casing (322, 330, 340) for supporting the

flexible substrate and the fixed substrate and accommodating the oscillator therewithin;

5 a plurality of lower electrodes (F1 to F5) provided on an upper surface of the flexible substrate;

10 a plurality of upper electrodes (E0) provided on a lower surface of the fixed substrate and disposed at positions respectively opposite to the plurality of lower electrodes;

15 a plurality of piezo resistance elements (Rx1 to Rx4, Ry1 to Ry4, Rz1 to Rz4) provided on the upper surface of the flexible substrate;

20 means (711, 712) for applying an a.c. signal across a pair of lower and upper electrodes opposite to each other to thereby oscillate the oscillator in respective coordinate axial directions; and

25 means (350, 361, 362, 363) for detecting a change of a resistance value of said piezo resistance elements to thereby detect displacements in respective coordinate axial directions of the oscillator.

20 15. A multi-axial angular velocity sensor as set forth in claim 14,

25 wherein an XYZ three-dimensional coordinate system such that an X-axis and a Y-axis intersect with each other on a plane in parallel to a principal surface of the flexible substrate is defined; and

wherein a first lower electrode (F1) and a first upper electrode (E1) are disposed in a positive region of the X-axis, a second lower electrode (F2) and a second upper electrode (E2) are disposed in a negative region of the X-axis, a third lower electrode (F3) and a third upper electrode (E3) are disposed in a positive region of the Y-axis, a fourth lower electrode (F4) and a fourth upper electrode (E4) are disposed in a negative region of the Y-axis, a fifth lower electrode (F5) and a fifth upper electrode (E5) are disposed at a position corresponding to an origin, a first set of piezo resistance elements (Rx1 to Rx4) are disposed along the X-axis, a second set of piezo resistance elements (Ry1 to Ry4) are disposed along the Y-axis, and a third set of piezo resistance elements (Rz1 to Rz4) are disposed along an arbitrary one axis on the XY plane.

16. A multi-axial angular velocity sensor as set forth in claim 15,

wherin there is further provided control means (740) for executing:

a first detecting operation for applying an a.c. signal across the fifth lower electrode (F5) and the fifth upper electrode (E5) and detecting changes of resistance values of the second set of piezo resistance elements (Ry1 to Ry4) with the oscillator being oscillated in the z-axis

direction, thus to detect an angular velocity component (ω_x) about the X-axis on the basis of said changes of the resistance values;

5 a second detecting operation for applying two a.c. signals having phases opposite to each other across the first lower electrode (F1) and the first upper electrode (E1) and across the second lower electrode (F2) and the second upper electrode (E2), respectively, and detecting changes of resistance values of the third set of piezo resistance elements (Rz1 to Rz4) with the oscillator being oscillated in the X-axis direction, thus to detect an angular velocity component (ω_y) about the Y-axis on the basis of the changes of said resistance values; and

10 15 a third detecting operation for applying two a.c. signals having phases opposite to each other across the third lower electrode (F3) and the third upper electrode (E3) and across the fourth lower electrode (F4) and the fourth upper electrode (E4), respectively, and detecting changes of resistance values of the first set of piezo resistance elements (Rx1 to Rx4) with the oscillator being oscillated in the Y-axis direction, thus to detect an angular velocity component (ω_z) about the Z-axis on the basis of said changes of the resistance values.

20 25 17. A multi-axial angular velocity sensor as set forth in claim 15,

wherein one party of the plural lower electrodes and the plural upper electrodes is constituted by a single electrode layer (E0).

5 18. A multi-axial angular velocity sensor as set forth in claim 17,

wherein one of the flexible substrate and the fixed substrate is constituted by conductive material, and the conductive substrate thus constituted itself is used as 40 a single electrode layer.

19. A multi-axial angular velocity sensor as set forth in claim 14,

wherein an XYZ three-dimensional coordinate system 15 such that an X-axis and a Y-axis intersect with each other on a plane in parallel to a principal surface of the flexible substrate is defined; and

wherein a first lower electrode (G1) and a first upper electrode (G6) are disposed in a first quadrant 20 region with respect to the XY plane, a second lower electrode (G2) and a second upper electrode (G7) are disposed in a second quadrant region with respect to the XY plane, a third lower electrode (G3) and a third upper electrode (G8) are disposed in a third quadrant region with 25 respect to the XY plane, a fourth lower electrode (G4) and a fourth upper electrode (G9) are disposed in a fourth

quadrant with respect to the XY plane, a fifth lower electrode (G5) and a fifth upper electrode (G10) are disposed at a position corresponding to an origin, a first set of piezo resistance elements (Rx1 to Rx4) are disposed along the X-axis, a second sets of piezo resistance elements (Ry1 to Ry4) are disposed along the Y-axis, and a third set of piezo resistance elements (Rz1 to Rz4) are disposed along an arbitrary one axis on the XY plane.

20. A multi-axial angular velocity sensor as set forth in claim 19,

wherein there is further provided control means (740) for executing:

15 a first detecting operation for applying an a.c. signal across the fifth lower electrode (G5) and the fifth upper electrode (G10) and detecting changes of resistance values of the second set of piezo resistance elements (Ry1 to Ry4) with the oscillator being oscillated in the Z-axis direction, thus to detect an angular velocity component 20 (ω_x) about the X-axis on the basis of said changes of resistance values;

25 a second detecting operation for applying a first a.c. signal across the first lower electrode (G1) and the first upper electrode (G6) and across the fourth lower electrode (G4) and the fourth upper electrode (G9), applying a second a.c. signal having a phase opposite to that of the

first a.c. signal across the second lower electrode (G2) and the second upper electrode (G7) and across the third lower electrode (G3) and the third upper electrode (G8), and detecting changes of resistance values of the third set 5 of piezo resistance elements (Rz1 to Rz4) with the oscillator being oscillated in the X-axis direction, thus to detect an angular velocity component (ω_y) about the Y-axis on the basis of said changes of resistance values; and

10 a third detecting operation for applying a first a.c. signal across the first lower electrode (G1) and the first upper electrode (G6) and across the second lower electrode (G2) and the second upper electrode (G7), applying a second a.c. signal having a phase opposite to that of the first a.c. signal across the third lower electrode (G3) and the third upper electrode (G8) and across the fourth lower electrode (G4) and the fourth upper electrode (G9), and detecting changes of resistance values of the first set of 15 piezo resistance elements (Rx1 to Rx4) with the oscillator being oscillated in the Y-axis direction, thus to detect an angular velocity component (ω_z) about the Z-axis on the basis of said changes of resistance values.

20 21. A multi-axial angular velocity sensor as set forth in claim 19,

25 wherein one party of the plural lower electrodes and the plural upper electrodes is constituted by a single

electrode layer (E0).

22. A multi-axial angular velocity sensor as set forth in claim 21,

5 wherein one of the flexible substrate and the fixed substrate is constituted by conductive material, and the conductive substrate thus constituted itself is used as a single electrode layer.

10 23. A multi-axial angular velocity sensor for detecting angular velocity components about respective coordinate axes in a three-dimensional coordinate system, comprising:

15 a flexible substrate (410) having flexibility;

a fixed substrate (420) disposed so as to oppose the flexible substrate with a predetermined distance therebetween above the flexible substrate;

20 an oscillator (440) fixed on the lower surface of the flexible substrate;

25 a sensor casing (450) for supporting the flexible substrate and the fixed substrate and accommodating the oscillator therewithin;

a plurality of lower electrodes (F1 to F5, F0) provided on an upper surface of the flexible substrate;

25 a plurality of upper electrodes (E1 to E5) provided on a lower surface of the fixed substrate and disposed at

positions respectively opposite to the plurality of lower electrodes;

a piezoelectric element (430) disposed between the lower electrodes and the upper electrodes;

5 means (711, 712) for applying an a.c. signal across a pair of lower and upper electrodes opposite to each other to thereby oscillate the oscillator in respective coordinate axial directions; and

10 means (721, 722) for detecting a potential produced across a pair of lower and upper electrodes opposite to each other, thus to detect displacements in respective coordinate axial directions of the oscillator.

15 24. A multi-axial angular velocity sensor as set forth in claim 23,

wherein an XYZ three-dimensional coordinate system such that an X-axis and a Y-axis intersect with each other on a plane in parallel to a principal surface of the flexible substrate is defined; and

20 wherein a first lower electrode (F1) and a first upper electrode (E1) are disposed in a positive region of the X-axis, a second lower electrode (F2) and a second upper electrode (E2) are disposed in a negative region of the X-axis, a third lower electrode (F3) and a third upper electrode (E3) are disposed in a positive region of the Y-axis, a fourth lower electrode (F4) and a fourth upper

electrode (E4) are disposed in a negative region of the Y-axis, and a fifth lower electrode (F5) and a fifth upper electrode (E5) are disposed at a position corresponding to an origin.

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25. A multi-axial angular velocity sensor as set forth in claim 24,

wherein the piezoelectric element is composed of a first portion interposed between the first lower electrode (F1) and the first upper electrode (E1), a second portion interposed between the second lower electrode (F2) and the second upper electrode (E2), a third portion interposed between the third lower electrode (F3) and the third upper electrode (E3), a fourth portion interposed between the fourth lower electrode (F4) and the fourth upper electrode (E4), and a fifth portion interposed between the fifth lower electrode (F5) and the fifth upper electrode (E5), a polarization characteristic with respect to the first, third and fifth portions and a polarization characteristic with respect to the second and fourth portions being caused 15 to be opposite to each other.

20 26. A multi-axial angular velocity sensor as set forth in claim 24,

25 wherein a plurality of physically divided piezoelectric elements are used.

27. A multi-axial angular velocity sensor as set forth in claim 24,

wherein there is further provided control means
5 (740) for executing:

a first detecting operation for applying an a.c. signal across the fifth lower electrode (F5) and the fifth upper electrode (E5) and detecting, with the oscillator being oscillated in the Z-axis direction, a sum of a voltage produced across the third lower electrode (F3) and the third upper electrode (E3) and a voltage produced between the fourth lower electrode (F4) and the fourth upper electrode (E4), thus to detect an angular velocity component (ω_x) about the X-axis on the basis of said sum;

15 a second detecting operation for respectively applying a.c. signals across the first lower electrode (F1) and the first upper electrode (E1) and across the second lower electrode (F2) and the second upper electrode (E2) and detecting, with the oscillator being oscillated in the X-axis direction, a voltage produced across the fifth lower electrode (F5) and the fifth upper electrode (E5), thus to detect an angular velocity component (ω_y) about the Y-axis on the basis of said voltage produced; and

25 a third detecting operation for respectively applying
a.c. signals across the third lower electrode (F3) and the
third upper electrode (E3) and across the fourth lower

electrode (F4) and the fourth upper electrode (E4) and detecting, with the oscillator being oscillated in the Y-axis direction, a sum of a voltage produced across the first lower electrode (F1) and the first upper electrode 5 (E1) and a voltage produced across the second lower electrode (F2) and the second upper electrode (E2), thus to detect an angular velocity component (ω_z) about the Z-axis on the basis of said sum.

28. A multi-axial angular velocity sensor as set forth in claim 24,

wherein one party of the plural lower electrodes and the plural upper electrode is constituted by a single electrode layer (F0).

29. A multi-axial angular velocity sensor as set forth in claim 28,

wherein one of the flexible substrate and the fixed substrate is constituted by conductive material, and 20 the conductive substrate (480) thus constituted itself is used as a single electrode layer (F0).

30. A multi-axial angular velocity sensor for detecting angular velocity components about respective 25 coordinate axes in a three-dimensional coordinate system, comprising:

100
a piezoelectric element (520) in a plate form;
a plurality of upper electrodes (L1 to L16) provided
on an upper surface of the piezoelectric element;

5 a plurality of lower electrodes (M1 to M16) provided
on a lower surface of the piezoelectric element and disposed
at positions respectively opposite to the plurality of
upper electrodes;

10 a flexible substrate (510) fixed on a lower surface
of the lower electrode and having flexibility;

15 an oscillator (550) fixed on a lower surface of
the flexible substrate;

20 a sensor casing (560) for supporting the flexible
substrate and accommodating the oscillator therewithin;

25 means (711, 712) for applying an a.c. signal
across a pair of lower and upper electrodes opposite to
each other to thereby oscillate the oscillator in respective
coordinate axial directions; and

30 means (721, 722) for detecting a potential produced
across a pair of lower and upper electrodes opposite to
each other, thus to detect displacements in respective
coordinate axial directions of the oscillator.

31. A multi-axial angular velocity sensor as set
forth in claim 30,

35 wherein an XYZ three-dimensional coordinate system
such that an X-axis and a Y-axis intersect with each other

on a plane in parallel to a principal surface of the flexible substrate is defined, and an arbitrary W-axis intersecting, at an origin of the coordinate system, with the X-axis and the Y-axis is defined on the XY plane;

5 wherein first and second upper electrodes (L1, L2) of the plurality of upper electrodes are provided at a position such that a projected image onto the XY plane is located at a negative portion of the X-axis, and third and fourth upper electrodes (L3, L4) of the plurality of upper electrodes are provided at a position such that a projected image onto the XY plane is located at a positive portion of the X-axis;

10 wherein fifth and sixth upper electrodes (L5, L6) of the plurality of upper electrodes are provided at a position such that a projected image onto the XY plane is located at a negative portion of the Y-axis, and seventh and eighth upper electrodes (L7, L8) of the plurality of upper electrodes are provided at a position such that a projected image onto the XY plane is located at a positive portion of the Y-axis;

15 wherein ninth and tenth upper electrodes (L9, L10) of the plurality of upper electrodes are provided at a position such that a projected image onto the XY plane is located at a negative portion of the W-axis, and eleventh and twelfth upper electrodes (L11, L12) of the plurality of upper electrodes are provided at a position such that a

projected image onto the XY plane is located at a positive portion of the W-axis; and

wherein the second, third, sixth, seventh, tenth and eleventh upper electrodes are provided at a position close to the origin relative to the first, fourth, fifth, eighth, ninth and twelfth upper electrodes.

32. A multi-axial angular velocity sensor as set forth in claim 31,

wherein the piezoelectric element is composed of a first portion interposed between the first upper electrode (L1) and the first lower electrode (M1), a second portion interposed between the second upper electrode (L2) and the second lower electrode (M2), a third portion interposed between the third upper electrode (L3) and the third lower electrode (M3), a fourth portion interposed between the fourth upper electrode (L4) and the fourth lower electrode (M4), a fifth portion interposed between the fifth upper electrode (L5) and the fifth lower electrode (M5), a sixth portion interposed between the sixth upper electrode (L6) and the sixth lower electrode (M6), a seventh portion interposed between the seventh upper electrode (L7) and the seventh lower electrode (M7), an eighth portion interposed between the eighth upper electrode (L8) and the eighth lower electrode (M8), a ninth portion interposed between the ninth upper electrode (L9) and the ninth lower electrode

10 (M9), a tenth portion interposed between the tenth upper electrode (L10) and the tenth lower electrode (M10), an eleventh portion interposed between the eleventh upper electrode (L11) and the eleventh lower electrode (M11), and
5 a twelfth portion interposed between the twelfth upper electrode (L12) and the twelfth lower electrode (M12), the polarization characteristic with respect to the first, third, fifth, seventh, ninth and twelfth portions and the polarization characteristic with respect to the second, fourth, sixth, eighth, tenth and eleventh portions being caused to be opposite to each other.

15 33. A multi-axial angular velocity sensor as set forth in claim 31,

wherein a plurality of physically divided piezoelectric elements are used.

20 34. A multi-axial angular velocity sensor as set forth in claim 31,

wherein there is further provided control means (740) for executing:

25 a first detecting operation for applying an a.c. signal across the ninth upper electrode (L9) and the ninth lower electrode (M9), across the tenth upper electrode (L10) and the tenth lower electrode (M10), across the eleventh upper electrode (L11) and the eleventh lower

electrode (M11), and across the twelfth upper electrode (L12) and the twelfth lower electrode (M12) and detecting, with the oscillator being oscillated in the Z-axis direction, a potential produced across the fifth upper electrode (L5) and the fifth lower electrode (M5), a potential produced across the sixth upper electrode (L6) and the sixth lower electrode (M6), a potential produced across the seventh upper electrode (L7) and the seventh lower electrode (M7), and a potential produced across the eighth upper electrode (L8) and the eighth lower electrode (M8), thus to detect an angular velocity component (ω_x) about the X-axis on the basis of said respective potentials produced;

10 a second detecting operation for applying an a.c. signal across the first upper electrode (L1) and the first lower electrode (M1), across the second upper electrode (L2) and the second lower electrode (M2), across the third upper electrode (L3) and the third lower electrode (M3), and across the fourth upper electrode (L4) and the fourth lower electrode (M4) and detecting, with the oscillator being oscillated in the X-axis direction, a potential produced across the ninth upper electrode (L9) and the ninth lower electrode (M9), a potential produced across the tenth upper electrode (L10) and the tenth lower electrode (M10), a potential produced across the eleventh upper electrode (L11) and the eleventh lower electrode (M11), and a potential produced across the twelfth upper electrode

(L12) and the twelfth lower electrode (M12), thus to detect an angular velocity component (ω_y) about the Y-axis on the basis of said respective potentials produced; and

5 a third detecting operation for applying an a.c. signal across the fifth upper electrode (L5) and the fifth lower electrode (M5), across the sixth upper electrode (L6) and the sixth lower electrode (M6), across the seventh upper electrode (L7) and the seventh lower electrode (M7), and across the eighth upper electrode (L8) and the eighth lower electrode (M8) and detecting, with the oscillator being oscillated in the Y-axis direction, a potential produced across the first upper electrode (L1) and the first lower electrode (M1), a potential produced across the second upper electrode (L2) and the second lower electrode (M2), a potential produced across the third upper electrode (L3) and the third lower electrode (M3), and a potential produced across the fourth upper electrode (L4) and the fourth lower electrode (M4), thus to detect an angular velocity component (ω_z) about the Z-axis on the basis of 15 said respective potentials produced.

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35. A multi-axial angular velocity sensor as set forth in claim 31,

25 wherein one party of the plural lower electrodes and the plural upper electrodes is constituted by a single electrode layer (M0).

36. A multi-axial angular velocity sensor as set forth in claim 35,

wherein one of the flexible substrate and the fixed substrate is constituted by conductive material, and
5 the conductive substrate (570) thus constituted itself is used as a single electrode layer (M0).

37. A multi-axial angular velocity sensor for detecting angular velocity components about respective coordinate axes in a three-dimensional coordinate system, comprising:

an oscillator (610) comprised of magnetic material, which is disposed at an origin position of the coordinate system;

15 a sensor casing (620, 630) for accommodating the oscillator therewithin;

connection means (640, 650) for connecting the oscillator to the sensor casing in a state having a degree of freedom such that the oscillator can move in respective
20 coordinate axial directions;

a first coil pair (J1, J2) attached to the sensor casing at positive and negative positions of a first coordinate axis of the coordinate system;

25 a second coil pair (J3, J4) attached to the sensor casing at positive and negative positions of a second coordinate axis of the coordinate system;

10 a third coil pair (J5, J6) attached to the sensor casing at positive and negative positions of a third coordinate axis of the coordinate system;

15 5 excitation means (711, 712) for delivering an a.c. signal to the respective coil pairs to thereby oscillate the oscillator in respective coordinate axial directions; and

10 10 displacement detecting means (721, 722) for detecting displacements in the respective coordinate axial directions of the oscillator on the basis of changes in impedance of the respective coil pairs.

15 38. A multi-axial angular velocity sensor as set forth in claim 37,

15 15 wherein there is further provided control means (740) for executing:

10 20 first detecting operation for delivering an a.c. signal to the first coil pair and detecting a change of impedance of the second coil pair with the oscillator being oscillated in the first axial direction, thus to detect an angular velocity component about the third axis on the basis of said change of impedance;

15 25 second detecting operation for delivering an a.c. signal to the second coil pair and detecting a change of impedance of the third coil pair with the oscillator being oscillated in the third axial direction, thus to detect an

angular velocity component about the first axis on the basis of said change of impedance; and

third detecting operation for delivering an a.c. signal to the third coil pair and detecting a change of 5 impedance of the first coil pair with the oscillator being oscillated in the third axial direction, thus to detect an angular velocity component about the second axis on the basis of said change of impedance.

10 39. A multi-axial angular velocity sensor for detecting angular velocity components about at least two coordinate axes in a three-dimensional coordinate system, comprising:

15 an oscillator (130; 211; 241; 260; 321; 440; 550; 610) having mass;

a sensor casing (140; 220, 230; 270, 280, 290; 322, 330, 340; 450; 560; 620, 630, 660) for accommodating said oscillator therewithin;

20 connection means (110; 212; 252; 312; 410; 510; 640, 650) for connecting the oscillator to the sensor casing in a state having a degree of freedom such that the oscillator can move in respective coordinate axial directions;

25 excitation means (E0 to E5, F0 to F5; G0 to G10; D1 to D16; J1 to J6) for oscillating the oscillator in at least two coordinate axial directions; and

displacement detecting means (E0 to E5, F0 to F5;

G0 to G10; Rx1 to Rx4; Ry1 to Ry4, Rz1 to Rz4; D1 to D16; J1 to J6) for detecting displacements in at least two coordinate axial directions of the oscillator.

5 40. A multi-axial angular velocity sensor as set forth in claim 39,

wherein there is further provided control means (740) for executing:

10 first detecting operation for giving an indication to the excitation means so as to oscillate the oscillator in a first coordinate axial direction, and for giving an indication to the displacement detecting means so as to detect a displacement in a second coordinate axial direction of the oscillator, thus to determine an angular velocity component about a third coordinate axis on the basis of the detected displacement; and

15 second detecting operation for giving an indication to the excitation means so as to oscillate the oscillator in the second coordinate axial direction, and for giving an indication to the displacement detecting means so as to detect a displacement in the third coordinate axial direction of the oscillator, thus to determine an angular velocity component about the first coordinate axis on the basis of the detected displacement.

41. A multi-axial angular velocity sensor for detecting angular velocity components about two coordinate axes (Y, Z) in a three-dimensional coordinate system, comprising:

5 an oscillator (130; 211; 241; 260; 321; 440; 550; 610) having mass;

10 a sensor casing (140; 220, 230; 270, 280, 290; 322, 330, 340; 450; 560; 620, 630, 660) for accommodating said oscillator therewithin;

15 connection means (110; 212; 252; 312; 410; 510; 640, 650) for connecting the oscillator to the sensor casing in a state having a degree of freedom such that the oscillator can move in respective coordinate axial (X, Y, Z) directions;

20 15 excitation means (E0 to E2, F0 to F2; G0 to G4, G6 to G9; D1 to D4; J1, J2) for oscillating the oscillator in a first coordinate axial (X) direction; and

25 20 displacement detecting means (E0, E3 to E5, F0, F3 to F5; G0 to G10; Ryl to Ryl, Rz1 to Rz1; D5 to D16; J3 to J6) for detecting displacements in a second coordinate axial (Y) direction and in a third coordinate axial (Z) direction of the oscillator;

to detect an angular velocity component about the third coordinate axis (Z) on the basis of a displacement in the second coordinate axial (Y) direction detected by the displacement detecting means; and

to detect an angular velocity component about the second coordinate axis (Y) on the basis of a displacement in the third coordinate axial (Z) direction detected by the displacement detecting means.

5

42. A multi-axial angular velocity sensor for detecting angular velocity components about two coordinate axes (X, Y) in a three-dimensional coordinate system, comprising:

an oscillator (130; 211; 241; 260; 321; 440; 550; 610) having mass;

a sensor casing (140; 220, 230; 270, 280, 290; 322, 330, 340; 450; 560; 620, 630, 660) for accommodating said oscillator therewithin;

connection means (110; 212; 252; 312; 410; 510; 640, 650) for connecting the oscillator to the sensor casing in a state having a degree of freedom such that the oscillator can move in respective coordinate axial (X, Y, Z) directions;

20 excitation means (E0 to E4, F0 to F4; G0 to G4, G6 to G9; D1 to D8; J1 to J4) for oscillating the oscillator in a first coordinate axial (X) direction and in a second coordinate axial (Y) direction; and

25 displacement detecting means (E0, E5, F0, F5; G0, G5, G10; Rz1 to Rz1; D9 to D16; J5, J6) for detecting a displacement in a third coordinate axial (Z) direction of

the oscillator;

to detect an angular velocity component about the second coordinate axis (Y) on the basis of a displacement in the third coordinate axial (Z) direction detected by the displacement detecting means when the oscillator is oscillating in the first coordinate axial (X) direction; and

to detect an angular velocity component about the first coordinate axis (X) on the basis of a displacement in the third coordinate axial (Z) direction detected by the displacement detecting means when the oscillator is oscillating in the second coordinate axial (Y) direction.

43. A multi-axial angular velocity sensor for detecting angular velocity components about respective coordinate axes (X, Y, Z) in a three-dimensional coordinate system, comprising:

an oscillator (130; 211; 241; 260; 321; 440; 550; 610) having mass;

a sensor casing (140; 220, 230; 270, 280, 290; 322, 330, 340; 450; 560; 620, 630, 660) for accommodating said oscillator therewithin;

connection means (110; 212; 252; 312; 410; 510; 640, 650) for connecting the oscillator to the sensor casing in a state having a degree of freedom such that the oscillator can move in respective coordinate axial directions;

excitation means (E0 to E4, F0 to F4; G0 to G4, G6 to G9; D1 to D8; J1 to J4) for oscillating the oscillator in a first coordinate axial (X) direction and in a second coordinate axial (Y) direction; and

5 displacement detecting means (E0, E3 to E5, F0, F3 to F5; G0 to G10; Ry1 to Ry1, Rz1 to Rz1; D5 to D16; J3 to J6) for detecting a displacement in the second coordinate axial (Y) direction and a displacement in a third coordinate axial (Z) direction of the oscillator;

10 to detect an angular velocity component about the third coordinate axis (Z) on the basis of a displacement in the second coordinate axial (Y) direction detected by the displacement detecting means when the oscillator is oscillating in the first coordinate axial (X) direction,

15 to detect an angular velocity component about the second coordinate axis (Y) on the basis of a displacement in the third coordinate axial (Z) direction detected by the displacement detecting means when the oscillator is oscillating in the first coordinate axial (X) direction,

20 and

25 to detect an angular velocity component about the first coordinate axis (X) on the basis of a displacement in the third coordinate axial (Z) direction detected by the displacement detecting means when the oscillator is oscillating in the second coordinate axial (Y) direction.